

FLIGHT SERVICE EVALUATION
OF KEVLAR-49/EPOXY COMPOSITE
PANELS IN WIDE-BODIED COMMERCIAL
TRANSPORT AIRCRAFT

THIRD ANNUAL
FLIGHT SERVICE EVALUATION REPORT

By

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By

LOCKHEED-CALIFORNIA COMPANY
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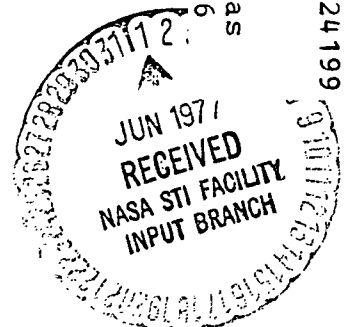


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FOREWORD

This is the third annual flight service evaluation report on the condition of Kevlar-49 fairing panels installed on three L-1011's under NASA Contract NAS 1-11621, "Flight Service Evaluation of Kevlar-49 Composite Panels in Wide-Bodied Commercial Transport Aircraft." The manufacture and installation of these panels was completed in February 1973 and reported in NASA CR-112250 dated March 1973 (Ref. 1). The results of inspections after the first and second years of flight service were reported in Refs. 2 and 3. Annual reports will be issued describing service performance after four and five years of service.

This program is being administered by the Langley Research Center, National Aeronautics and Space Administration with Mr. Benson Dexter of the Materials Division as the Project Engineer.

This program is being performed by the Lockheed-California Company with Robert H. Stone the Program Leader, with assistance provided by T. L. Crawford, D. H. Horadam, R. S. Beck, J. Luney and B. L. Woods of the Product Support Branch; and J. Wooley of the Materials and Producibility Department.



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ABSTRACT

Kevlar-49 fairing panels, installed as flight service components on three L-1011s, were inspected after three years' service, and found to be performing satisfactorily. There are six Kevlar-49 panels on each aircraft, including sandwich and solid laminate wing-body panels, and 150°C (300°F) service aft engine fairings. The three L-1011s are one each of Eastern, Air Canada, and TWA aircraft. The fairings have accumulated a total of 23,093 hours, with one ship set having 10,126 hours service as of November 28, 1976. The inspections were conducted at the airlines' major maintenance bases with the participation of Lockheed Engineering.

As in the previous inspections, only minor defects such as surface impact damage, and minor elongation and fraying of fastener holes were noted. None of the damage required corrective action, and are for the most part comparable to damage noted on fiberglass fairings.

The service history to date indicates that Kevlar-49 epoxy composite materials have satisfactory service characteristics for use in aircraft secondary structure.



SECTION 1

INTRODUCTION AND BACKGROUND

The subject program on flight service evaluation of Kevlar-49 fairings consists of fabrication, installation and flight service of eighteen secondary structural panels; six on each of three L-1011's. The three participating airlines are Eastern, TWA, and Air Canada. Fabrication and installation of the panels was completed in February 1973, with initiation of flight service occurring in early 1973 on all three aircraft.

The six fairings are all similar to baseline fiberglass designs in which Kevlar-49 fabric, (comparable in fabric weave and thickness per ply to the fiberglass), was substituted for the fiberglass on a ply for ply basis. This required no other design changes or development of new tooling for layup and cure, but still provided a potential weight savings of 25-30 per cent. These six parts are as follows:

- o A left-hand and right-hand set of a large 152 cm x 170 cm (60 inch x 67 inch) sandwich wing-body fairing panel. The exterior skin is 0.05 cm (0.020 inch) thick with 1 ply 181 style Kevlar-49 fabric and 2 plies 120 style Kevlar-49 fabric. The interior skin is 0.04 cm (0.015 inch) thick with three plies of 120 style Kevlar-49 fabric. The honeycomb core is Nomex with 0.3 cm (1/8 inch) cells, and 0.048 gm/cm³ (3.0 lb/cu ft) density. Overall panel thickness is 0.3 cm (0.125 inch).
- o A left-hand and right-hand set of a small 23 cm x 84 cm (9 inch x 33 inch) approximately-solid laminate wing-body fillet panel. The laminate incorporates 9 plies of 181 style Kevlar-49 fabric and is approximately 0.2 cm (0.09 inch) thick.
- o A left-hand and right-hand set of an aft engine sandwich fairing- 76 cm x 183 cm (30 inch x 72 inch approximately). The skins are 0.05 cm (0.020 inch) thick with 1 ply 181 style Kevlar-49 fabric and 2 plies 120 style Kevlar-49 fabric. The Nomex core is identical to that used in the wing-body fairing, except for thickness, and the overall panel thickness is 0.64 cm (0.25 inch).



The Kevlar-49 panels all utilized the same resin system as the production fiberglass parts: A 120°C (250°F) curing, 82°C (180°F) service epoxy (Hexcel's F-155) for the wing-body fairing and fillet panels, and a 177°C (350°F) curing, 150°C (300°F) service epoxy (Hexcel's F-161) for the aft engine fairings. All of the parts have an outer layer of flame sprayed aluminum and topcoat applied according to standard production procedures used on the baseline fiberglass parts. The actual weight savings achieved by this direct substitution of Kevlar-49 for fiberglass averaged 26 per cent for the six parts. Further details on Kevlar-49 part design and fabrication are given in NASA CR-112250 (Ref. 1), which is the final report of the fabrication and installation phases of the program.

Under the original program plan, inspections of the Kevlar-49 parts were to take place annually in conjunction with regularly scheduled inspections at the airline maintenance bases. However, the first annual inspections of the TWA and Air Canada panels took place at Lockheed-California Company due to special circumstances, while the Eastern panels were inspected by Eastern personnel at Miami. Results of those inspections indicated no significant damage or deterioration of the parts other than minor impact damage, fastener hole elongation, and minor delaminations. Comparable damage was also noted on similar fiberglass parts. Further details are given in NASA CR-132647, the First Annual Flight Service Report (Ref. 2).

In order to obtain thorough information and documentation of part conditions, the inspection activity was expanded as follows for the second annual inspections of the Eastern and Air Canada panels:

- 1) A Lockheed Engineering representative was present for the inspections at Miami and Montreal.
- 2) Three of the six panels (one of each left-hand and right-hand set) were removed for thorough inspection, and to permit inspection of fastener holes and interior surface conditions.
- 3) The part condition was documented in summary form using special forms provided to the airlines.

Inspections of the Eastern panels were conducted in April 1975 in accordance with the above procedures. An inspection was also conducted of the Air Canada panels in 1975, but due to aircraft schedule problems only one



panel was removed for inspection. These second annual inspections, as with the first inspections, revealed no significant damages other than minor conditions also typical of fiberglass parts in service. Further details are given in NASA CR-132733, the Second Annual Flight Service Report (Ref. 3).

The TWA panels were removed after approximately one year (2400 hours) of service when the aircraft was taken out of service in April 1974, because of a cabin interior fire. The parts were not damaged and were returned to Lockheed for inspection. The parts were subsequently installed on a second TWA L-1011 for continuation of flight service testing. The reinstallation on TWA aircraft N31030 required some rework and repair of the panels, particularly in the case of the aft engine fairing panels, where relocation of all fastener holes was required. This rework activity is reported in detail in the Second Flight Service Report (Ref. 3). The aircraft on which these parts were reinstalled was delivered to TWA in August 1975.



SECTION 2

PANEL INSPECTIONS

The six Kevlar-49 fairings installed on Eastern Ship N314EA (Serial #1022) were inspected at the Miami Maintenance Base on May 10, 1976. The panels at that time had been in flight service approximately three years with 8736 flight hours and 4422 flights. In the intervening year since the previous inspection, the panels accumulated 2675 flight hours. The three right-hand panels were removed for inspection, as the three left-hand panels had been removed in 1975. The left-hand parts were inspected in-place on the aircraft. Inspection was by visual examination and coin tapping for delaminations and debonds. The three panels taken off the aircraft were cleaned to remove excessive dirt and residue, and then dried and weighed.

The fairings installed on Air Canada Ship CF-TNB-502 (Serial #1021) were inspected at the Montreal Maintenance Base on August 26, 1976. The Air Canada panels have also been in service for three years, but have accumulated fewer flight hours than the Eastern panels, with a total of 7452 flight hours and 3786 flights. Since the previous inspection in 1975, 3128 additional flight hours were accumulated. The three panels removed for inspection were the left-hand wing-body fairing, the left-hand wing-body fillet, and the right-hand aft engine fairing; and these panels were cleaned and weighed in the same manner as the Eastern panels. The opposite parts were inspected on the aircraft. In 1975, only the right-hand wing-body fillet had been removed, so the left-hand fillet was removed this year. The left-hand wing-body fairing and right-hand aft engine fairing had been observed in 1975 to have more damage conditions (impact cracks and loose paint respectively) than their opposite pairs, and were thus selected for removal. Inspection was by visual examination and coin tapping as with the Eastern panels.

The TWA panels were inspected on October 21, 1976 at TWA's Los Angeles Maintenance Base for the first time since their reinstallation on TWA Aircraft N31030 (Serial #1111). At that time, they had accumulated 2278 flight hours and 784 flights and had been in service on Ship 1111 for almost one year. The panels had accumulated 2404 flight hours and 1037 flights prior to their removal from TWA Ship #1026, and were inspected at Lockheed prior to their reinstallation. This was therefore the second inspection of these panels. The three panels removed for inspection were the right-hand wing-body fairing, the right-hand wing-body fillet, and the left-hand aft engine fairing. In each case, the part removed had required more rework during installation on Ship #1111 than the opposite part. Inspection procedures were the same for the TWA panels as the Eastern and Air Canada panels: weighing of the removed panels, visual examination, and coin tapping.

All three inspections were conducted with the participation of Lockheed Engineering, and with the assistance of airline maintenance personnel, particularly in removal and reinstallation of the panels. Photographs were taken of all panels and areas containing defects, damage, or other conditions of special interest. Photographs were provided by Air Canada in Montreal, by the Lockheed Photography Department at TWA, and by a commercial photographer at Eastern.



SECTION 3

DISCUSSION OF INSPECTION RESULTS

The Kevlar-49 panels on the three L-1011's were all in satisfactory condition with only minor impact damage, and some fraying and elongation of fastener holes. The impact damage was primarily on the two wing-body fairing panels which are subject to handling damage because of their proximity to cargo and galley loadings, and which are also subject to damage from rocks and foreign objects thrown up from the runway. The impact damage, as mentioned, is minor, and cracks observed in the 1975 inspection had not grown or propagated. Similar damage was observed on fiberglass panels in adjacent areas.

The fraying and elongation of fastener holes also represents minor damage having no deleterious effect on part serviceability. Hole elongation has been observed in fiberglass panels to a similar degree, and the elongation occurs on only a few of the holes in a random distribution indicating that the condition is not related to an inherent characteristic of Kevlar-49 in bearing. It has been noted primarily on the wing-body fillets, and appears to be related to installation problems, which may result in concentrated or nonuniform loading. Careful note has been made of the location of fastener holes on each of the parts which show a noticeable degree of elongation or deformation. In subsequent inspections these holes will be carefully examined for increased deformation, fraying, delamination or other possible conditions. To date, there has been no evidence of increased hole deformation with increasing service life.

The fraying of the fastener holes is a more general occurrence, and is the only condition noted on the Kevlar panels not observed on fiberglass parts. The fraying is a result of the condition of having a ductile fiber within a relatively brittle resin matrix, and the slight degree of fraying noted may be

an inherent characteristic of Kevlar-49 composites. Isolated holes in a part where the fraying is more pronounced appear to reflect installation problems in the same manner as the elongated holes. In fact, the elongated holes are invariably more frayed than other holes. As in the case of elongated holes, the location of holes with significantly greater than average fraying is being noted, and the condition of these holes will be monitored in future inspections.

A possible significant observation is the generally greater degree of fraying in the fastener holes on the aft engine fairings. The aft engine fairings, as previously mentioned, incorporate a 177°C (350°F) curing epoxy. The higher temperature epoxies are inherently more brittle than the 120°C (250°F) curing systems. The Kevlar-49 composites with these resins could therefore be more sensitive to hole drilling and installation techniques, and could also react to in-service loads in a manner producing more fraying.

A notably lesser degree of fraying in the Air Canada aft engine fairing inspected this year, compared to the two Eastern panels inspected in 1975 and 1976, indicate that the fraying may be primarily related to drilling and installation techniques. A striking illustration of the effect of installation procedures is the Air Canada right-hand fillet, observed in 1975 to be badly installed with a number of elongated holes. In 1976, after removal and reinstallation, the misalignment was no longer evident.

The TWA aft engine fairings, which had required considerable rework prior to installation in Ship 1111 (Ref. 3), provided an evaluation of repair procedures on Kevlar-49 parts. These panels were repaired using standard fiberglass field repair materials and techniques, and the satisfactory performance of these parts in service indicates that Kevlar-49 parts generally can be repaired in the same manner as fiberglass components, requiring no revision in airline maintenance procedures. The most significant rework on these parts was relocation of all fastener holes. The holes were filled with a glass filled epoxy, and one layer of epoxy impregnated 120 glass cloth on each surface was bonded to the fastener area before redrilling. Most of the new fastener holes were drilled partially through the filled areas, and a significantly greater degree of hole elongation was noted on these parts than on any

other parts. At the same time, with the surface layer of glass, no fraying whatever was observed. This is significant as an indication that fraying by itself may not be an indication of damage. It appears that the hole filling technique used was inadequate for this particular situation where all fastener holes were relocated, and the elongation here is basically unrelated to the substitution of Kevlar-49 for fiberglass.

The inner surfaces of the Kevlar-49 fairings have been almost completely free of any damage or defects, further indicating that impact is responsible for all cracks noted on exterior surfaces. The absence of delaminations or skin-core debonds on the Kevlar-49 panels is worthy of note, and indicates the feasibility of co-curing Kevlar-49 sandwich panels.

There has as yet been no evidence of Skydrol contamination of any of the Kevlar-49 parts, although this is a potential situation because of the presence of hydraulic lines behind the wing-body fairings and fillets. There have been some instances of paint loss, but not to an extent indicating any difference in surface characteristics of Kevlar-49 and fiberglass composites, and the flame sprayed aluminum has adhered very well to the Kevlar-49 surface. In some instances, bare Kevlar-49 has been exposed on the wing-body fillets, but this is an area protected from ultraviolet, and no damage to the surface has been observed in these areas.

All of the Kevlar-49 parts removed for inspection were weighed for determination of possible weight gains due to moisture pick-up. This does not appear to provide any true evidence of the relative moisture absorption of Kevlar-49 composites compared to fiberglass. The effects of paint loss, repainting, loss of sealant and resealing, repair patches and the accumulation of surface contaminants all mask any weight changes due to moisture.

SECTION 4

SUMMARY OF RESULTS AND CONCLUSIONS

After three years of service and nearly 10,000 flight hours, the Kevlar-49 panels are free of significant damage or defects; and Kevlar-49/epoxy composites appear to have service life capabilities for secondary structures equivalent to fiberglass/epoxy.

The minor damage that has been observed appears related to two factors which are independent of the substitution of Kevlar-49 for fiberglass. These are ground handling damage which appears to have caused the minor cracks in the wing-body fairings; and installation problems which appear to be responsible for some of the fastener hole deformation and fraying. Kevlar-49 appears resistant to damage propagation, as indicated by the absence of crack growth or any increased degree of hole deformation over succeeding years. Also, the limited degree of impact damage indicates Kevlar-49 is at least equivalent to fiberglass in impact resistance.

The Kevlar-49 panels have proved to be almost completely free of delaminations and skin-core debonds, which is a very significant indication of Kevlar-49 serviceability. There is also no evidence of deleterious effects on the Kevlar-49 parts from exposure to the service environment, moisture, or aircraft fluids.

The serviceability of the reworked TWA panels to date indicates that standard fiberglass repair materials and procedures can be used for repair of Kevlar-49 parts, thus requiring no modification of airline maintenance procedures.

REFERENCES

1. Wooley, J.H.; Paschal, D.R.; and Crilly, E.R.: Flight Service Evaluation of PRD-49/Epoxy Composite Panels in Wide-Bodied Commerical Transport Aircraft - Final Report, NASA CR-112250, March 1973.
2. Wooley, J.H.; Flight Service Evaluation of PRD-49/Epoxy Composite Panels in Wide-Bodied Commercial Transport Aircraft - First Annual Flight Service Report. NASA CR-132647, July 1974.
3. Stone, R.H.; Flight Service Evaluation of Kevlar-49/Epoxy Composite Panels in Wide-Bodied Commerical Transport Aircraft - Second Annual Flight Service Report. NASA CR-132733, October 1975.



APPENDIX I

DETAIL OBSERVATIONS OF KEVLAR-49 FAIRING PANELS - EASTERN AIR LINES AIRCRAFT N314EA (SERIAL NO. 1022) MAY 1976

Three of the six Kevlar-49 fairings were removed for detailed inspection, weighing, and inspection of fastener holes and the inner surface. These were the right-hand wing-body sandwich fairing, the right-hand solid laminate wing-body fillet, and the right-hand aft engine sandwich fairing. The three left-hand fairings were inspected in-place on the aircraft. Detail observations on the six parts are outlined below.

RIGHT-HAND WING-BODY FAIRING - P/N 1515599-110

- 1) The panel weight was 6.91 kg (15.24 lb).
- 2) The panel exterior appearance was satisfactory (Figure 1). Paint chipping was noted around the fasteners, and in some areas the paint had been sanded. Flame spray was intact in all areas, however.
- 3) Two cracks were observed on the exterior surface which had also been noted in the 1975 inspection. One was in the lower, forward area and was 0.8 cm (5/16 inch) in length (Figure 2), and the other was 0.3 cm (1/8 inch) long in the aft center area. Both were unchanged in appearance and had not propagated in the intervening year.
- 4) Two additional cracks were observed on the exterior which were not observed in 1975. One crack was 1.3 cm (1/2 inch) long extending inward from the forward edge between the 5th and 6th fastener holes from the top (Figure 3). A crack, 0.6 cm (1/4 inch) long, was noted near the exact center of the panel with an associated scratch in the paint extending several inches forward and upward. The flame spray was intact in this area. A slight ding was observed in the lower center area, with an associated 0.3 cm (1/8 inch) long indication which may have been only in the paint.
- 5) No skin-core delaminations were noted on the outer surface, associated with cracks or elsewhere.

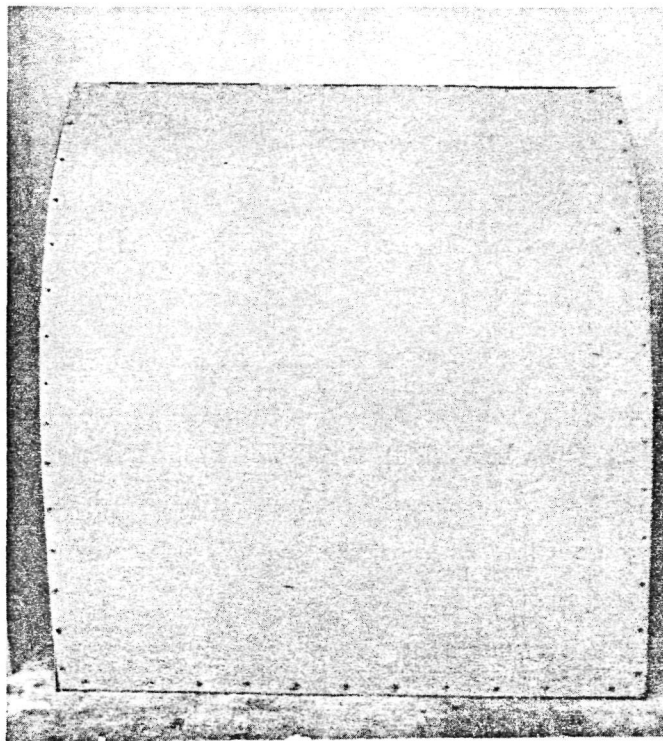


Figure 1. Eastern RH Wing-Body Fairing - Exterior Surface

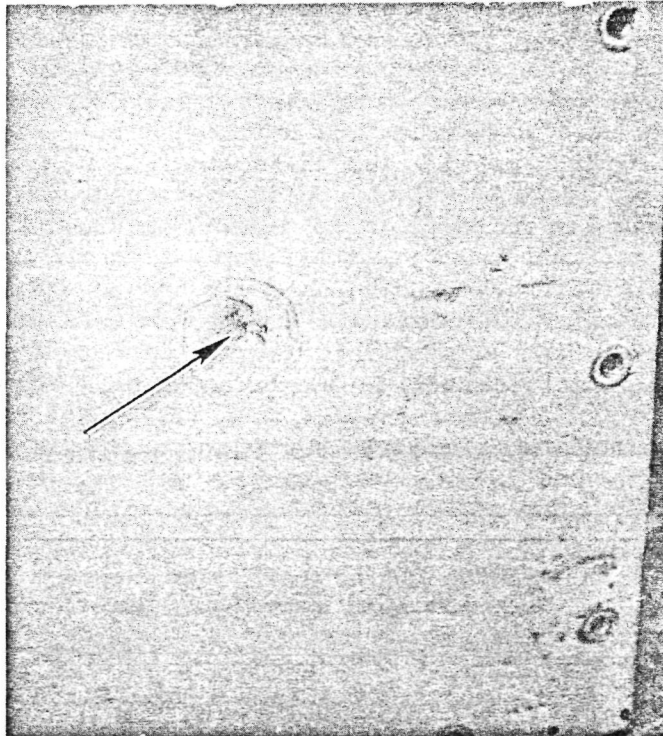


Figure 2. Eastern RH Wing-Body Fairing - 0.8 cm (5/16 inch) Crack, Exterior Surface

- 6) The interior surface appearance was satisfactory (Figure 4), with no cracks or debonding of Tedlar except as noted below around fastener holes. One very small debond area was located 23 cm (9 inches) from the top edge, associated with a vertical line (marked on the face) which was slightly depressed. A similar depressed line coinciding with this line was detected on the exterior face, and similar horizontal lines were detected 56 cm (22 inches) from the bottom edge. No other debonds were associated with these lines, which are apparently core splice locations.
- 7) The fastener holes showed no evidence of elongation or deformation. Some holes had a very slightly frayed appearance viewed from the exterior. The fastener holes viewed from the inner surface showed more evidence of fraying, but it was still to a minor degree. These included two holes on the lower aft edges and four holes on the lower forward edge with slight fraying. Along the bottom edge the fraying was more pronounced on some of the holes, with some slight associated Tedlar de-bonding. The laminate, immediately around six of these holes, showed a slight convex deformation

RIGHT-HAND WING-BODY FILLET - P/N 1545328-110

- 1) The panel weight was 1.01 kg (2.22 lb). $\triangle$
- 2) The exterior surface was in satisfactory condition with no surface damage to the Kevlar-49 despite considerable loss of paint in the upper, aft area (Figure 5). This area is not flame sprayed and the bare Kevlar was showing. In the lower area there was some paint loss and exposed flame spray around the fasteners.
- 3) The interior surface was free of defects or damage (Figure 6).
- 4) Fastener holes showed slight fraying when viewed from the inner surface. The fraying was more pronounced in four of the holes, and was accompanied by evident hole deformation (Figure 7). These included two holes each in the upper forward and lower aft portions of the part. The loss of paint mentioned previously was observed around these holes. The hole deformation was not visible from the exterior surface, but slight fraying of these holes could be observed from the exterior.

RIGHT-HAND AFT ENGINE FAIRING - P/N 1544685-117

- 1) The panel weight was 2.3 kg (5.10 lb). Initial weight was 2.0 kg (4.5 lb).
- 2) The exterior surface appearance was satisfactory with no damage, and only slight paint loss around some holes at the forward intercostal (Figure 8).

$\triangle$ This weight questionable because of discrepancy with Air Canada and TWA fillet weights



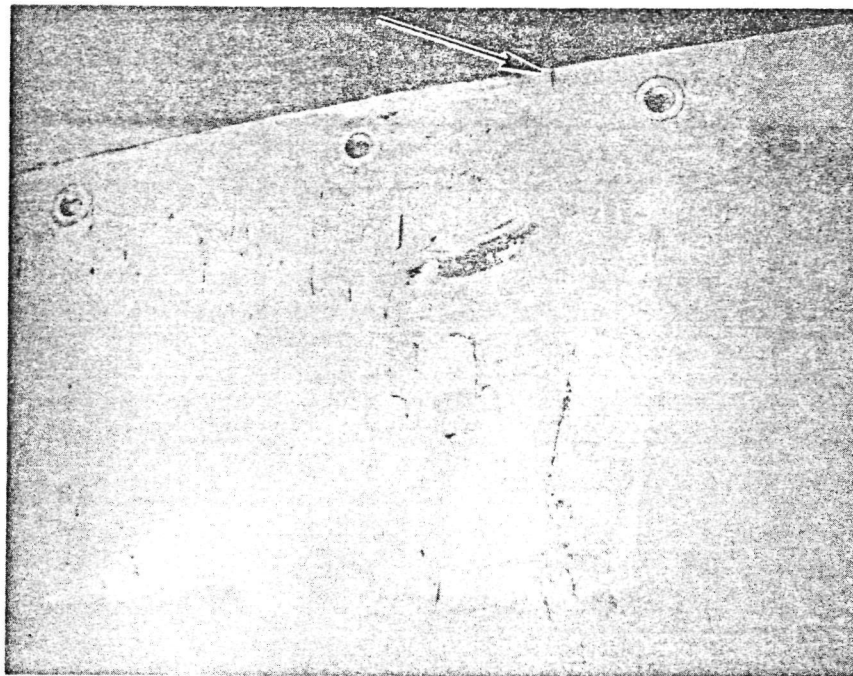


Figure 3. Eastern RH Wing-Body Fairing - Crack at Forward Edge
(With Paint Chipping in Surrounding Area)

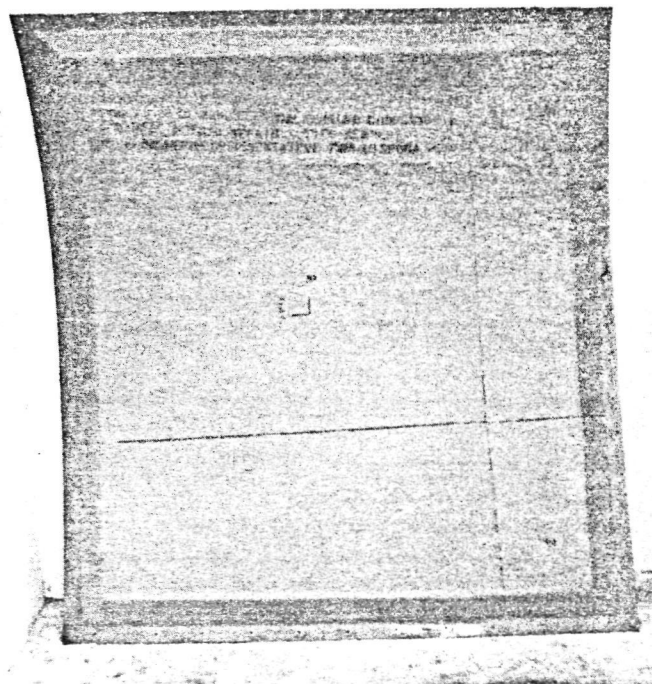


Figure 4. Eastern RH Wing-Body Fairing - Inner Surface

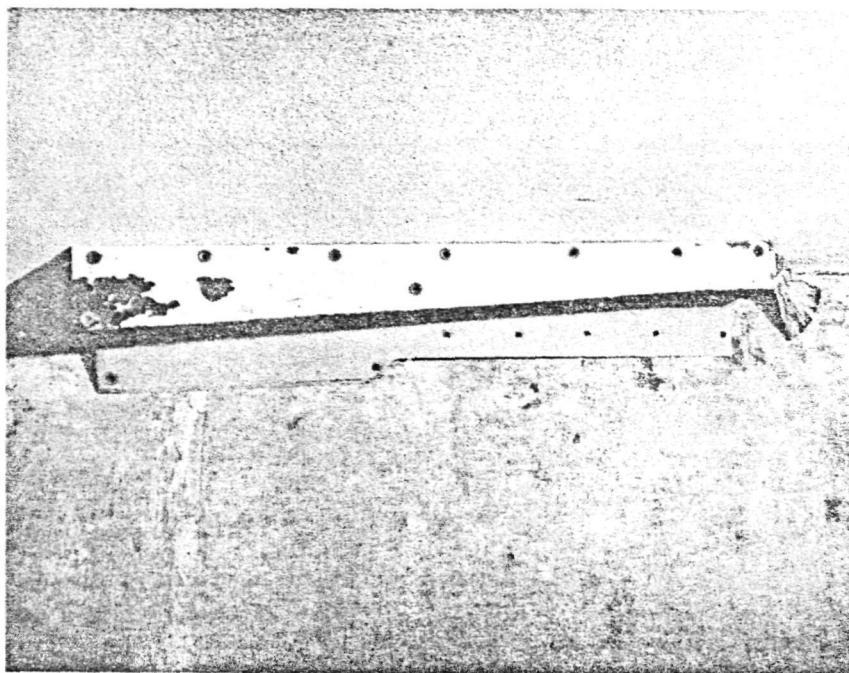


Figure 5. Eastern RH Wing-Body Fillet - Exterior Surface Showing Bare Kevlar-49 Area

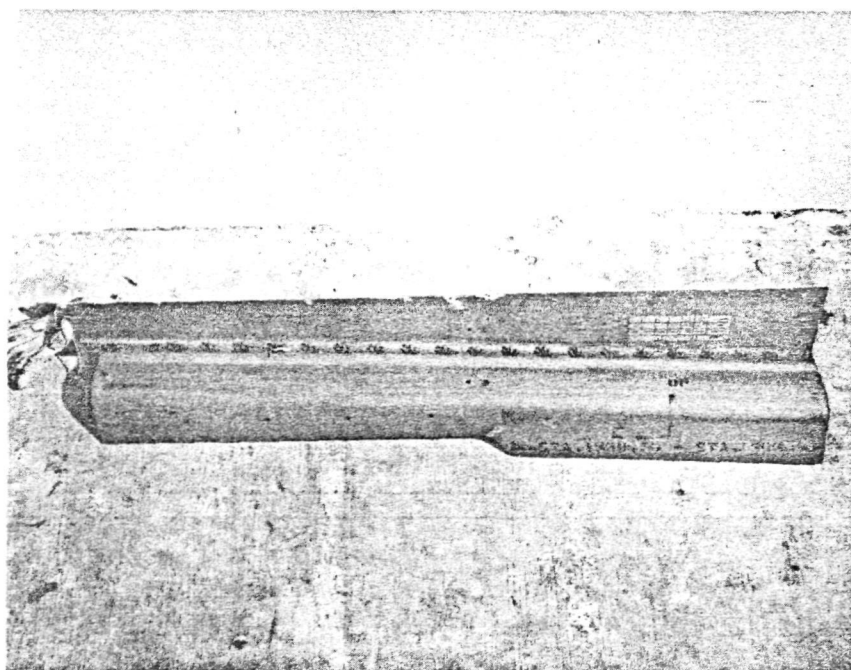


Figure 6. Eastern RH Wing-Body Fillet - Inner Surface

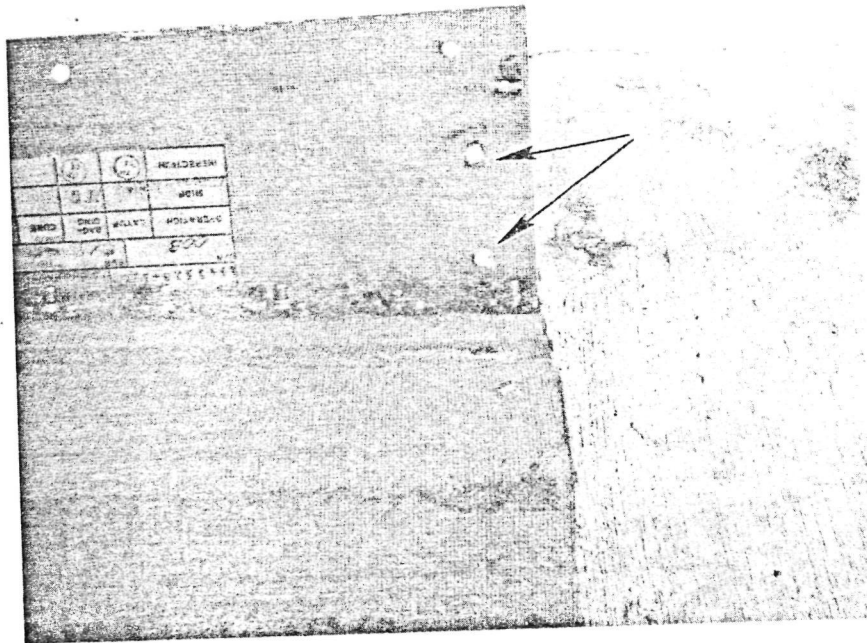


Figure 7. Eastern RH Wing-Body Fillet - Frayed and Elongated Fastener Holes

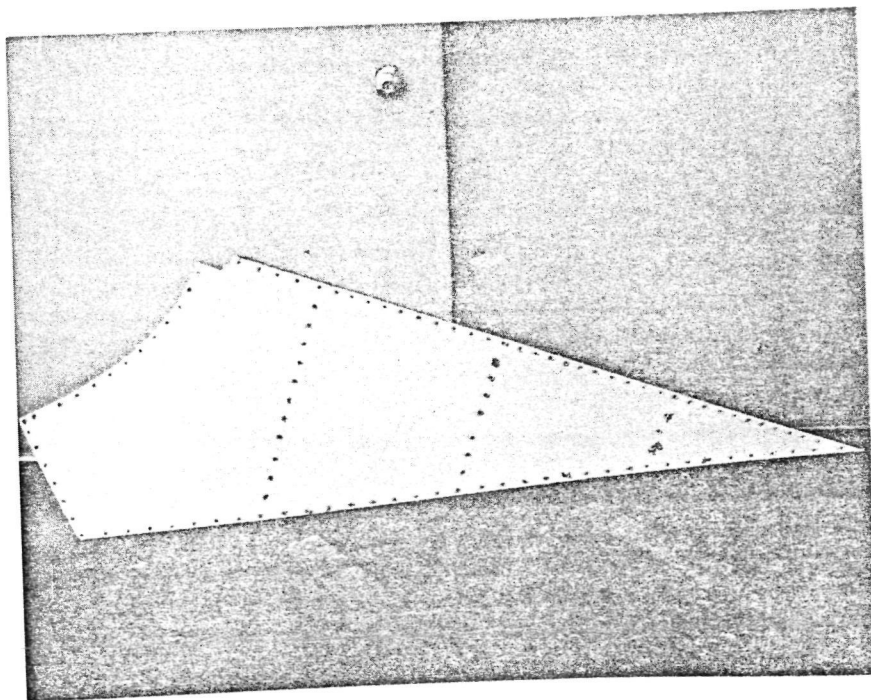


Figure 8. Eastern RH Aft Engine Fairing - Exterior Surface

- 3) The interior surface appearance was also satisfactory with no damage or Tedlar debond (Figure 9). No delaminations, cracks, or skin-core debonds were evident on either surface.
- 4) All fastener holes had a frayed appearance viewed from the inner surface (Figure 10). From the exterior, fraying was visible on about 1/2 of the fastener holes.

LEFT-HAND WING-BODY FAIRING - P/N 1515599-109

- 1) The exterior surface was satisfactory in appearance with slight paint chipping in a few small areas, mostly around fasteners, but with flame spray intact. Edge sealant was missing in some areas along the top edge. Rework on this panel included some repainting and application of new sealant.
- 2) An aluminum speed tape patch observed in the 1975 inspection was still intact (Figure 11), but with a corner torn off exposing the original paint. There was no evidence of propagation of the original defect.
- 3) No cracks, delaminations, or debonds were observed other than the patched area. The panel surface was considerably cleaner than noted in the 1975 inspection.
- 4) Some gaps were observable between the fastener head and panel surfaces. This occurred in fasteners in the upper forward edge and the upper aft edge.

LEFT-HAND WING-BODY FILLET - P/N 1545328-109

- 1) The exterior surface was free of damage or defects except for a gouged spot 0.5 cm (3/16 inch) long extending through the flame spray and surface layers.
- 2) Gaps were noted between several fastener heads and the panel surface. These gaps were more severe than those noted on the wing-body fairing with the fasteners more noticeably out of line (Figure 12). The gaps were particularly noticeable on two fasteners in the forward portion of the lower edge, and on one fastener in the forward, upper edge. A slight convexity of the panel was observed on the aft lower edge. This condition was noted on an Air Canada fillet in 1975, and appears to be related to installation problems.

LEFT-HAND AFT ENGINE FAIRING - P/N 1538592-129

- 1) No visible defects or damage were noted on the exterior surface. A few fasteners on the center, aft edge were observed to be very slightly out of line with slight gaps between the fastener head and panel surface.



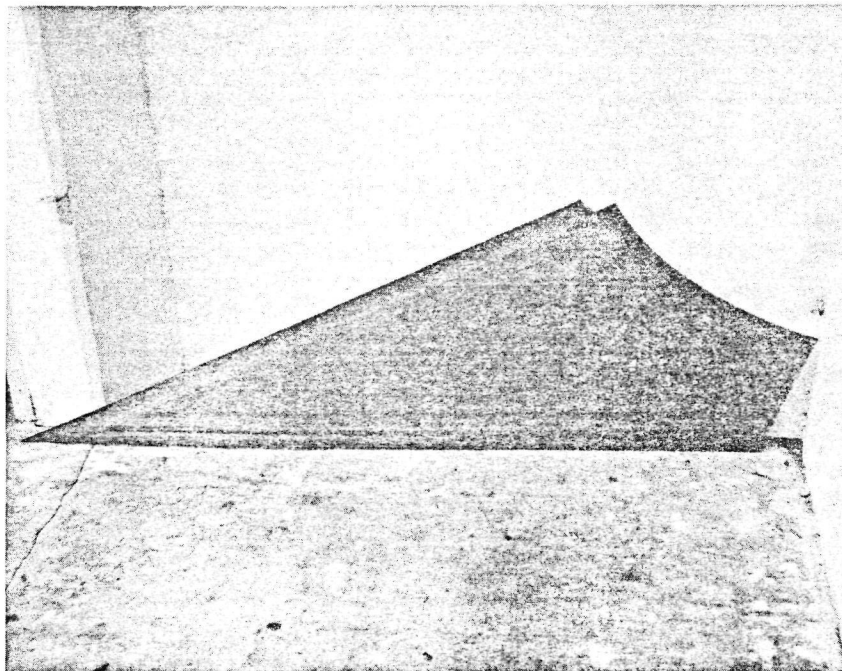


Figure 9. Eastern RH Aft Engine Fairing - Inner Surface

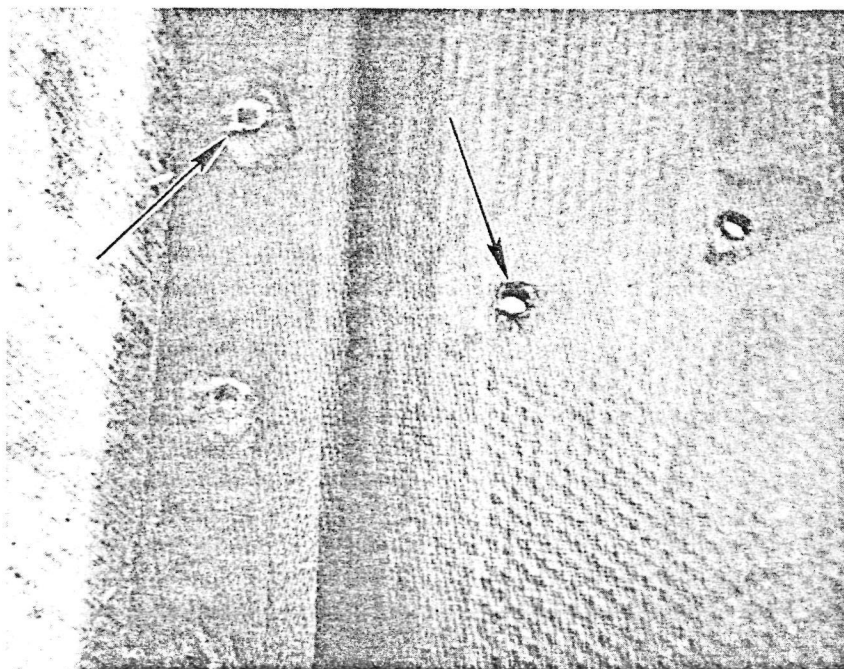


Figure 10. Eastern RH Aft Engine Fairing - Frayed Fastener Holes

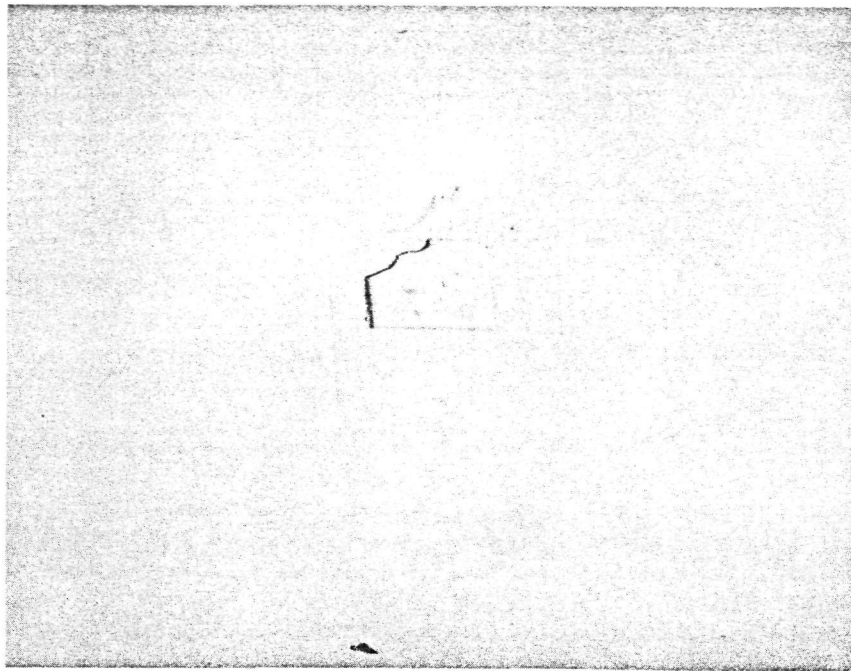


Figure 11. Eastern LH Wing-Body Fairing - External Tape Patch

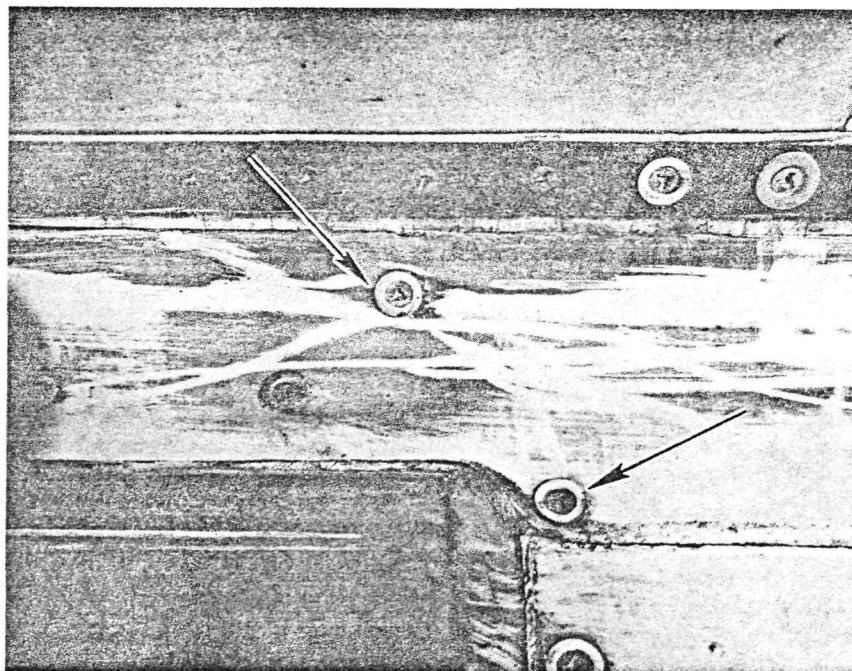


Figure 12. Eastern LH Wing-Body Fairing - With Misaligned Fasteners

APPENDIX II

DETAIL OBSERVATIONS OF KEVLAR-49 FAIRING PANELS - AIR CANADA AIRCRAFT CF-TNB-502 (SERIAL NO. 1021), AUGUST 1976

Three of the six Kevlar-49 fairings were removed for detailed inspection, weighing, and inspection of fastener holes and the inner surface. These were the left-hand wing-body sandwich fairing, the left-hand solid laminate wing-body fillet, and the right-hand aft engine fairing. The other three parts were inspected in-place on the aircraft. Detail observations on the six parts are outlined below.

LEFT-HAND WING-BODY FAIRING - P/N 1515599-109

- 1) The panel weight was 6.72 kg (14.81 lb). Original weight was 7.0 kg (15.5 lb).
- 2) The exterior surface was satisfactory in appearance (Figure 13), except for one crack which was the result of impact damage. This was a 3.2 cm (1-1/4 inch) long crack in the upper aft area (Figure 14), with a slight delaminated area extending 0.6 cm (1/4 inch) to either side of the crack. This crack was observed in the 1975 inspection and had not grown or propagated. This was the only delamination or skin-core de-bond noted on either surface. A second crack-like indication 1.3 cm (1/2 inch) long, observed in the 1975 inspection, was not visible and apparently had only been in the paint. Extensive paint chipping and blistering were observed around the fastener holes, but flame spray was intact.
- 3) The interior surface was satisfactory in appearance with no cracks, delaminations, skin-core or Tedlar de-bonds.
- 4) Slight fraying was observed on most fastener holes. No hole elongation was observed, but there was a slight convex laminate deformation around several holes on the lower edge (Figure 15).

LEFT-HAND WING-BODY FILLET - P/N 1545328-109

- 1) The panel weight was 0.6 kg (1.31 lb).
- 2) There were no cracks or observable defects or damage on either surface (Figure 16). The upper and lower areas both had extensive

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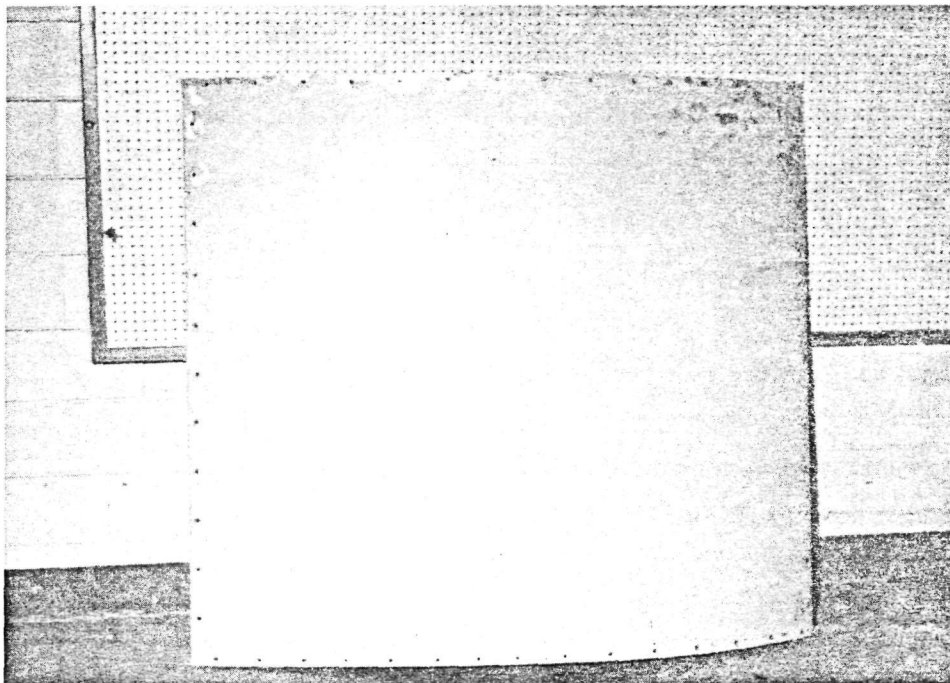


Figure 13. Air Canada LH Wing-Body Fairing - Exterior Surface

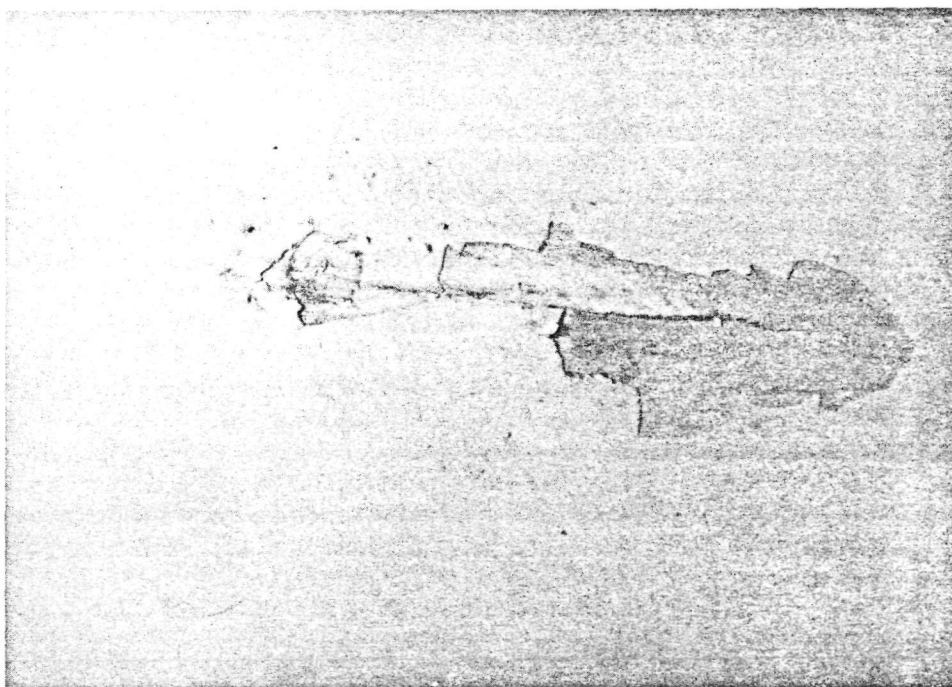


Figure 14. Air Canada LH Wing-Body Fairing - 3.2 cm (1-1/4 inch)
Crack, Exterior Surface

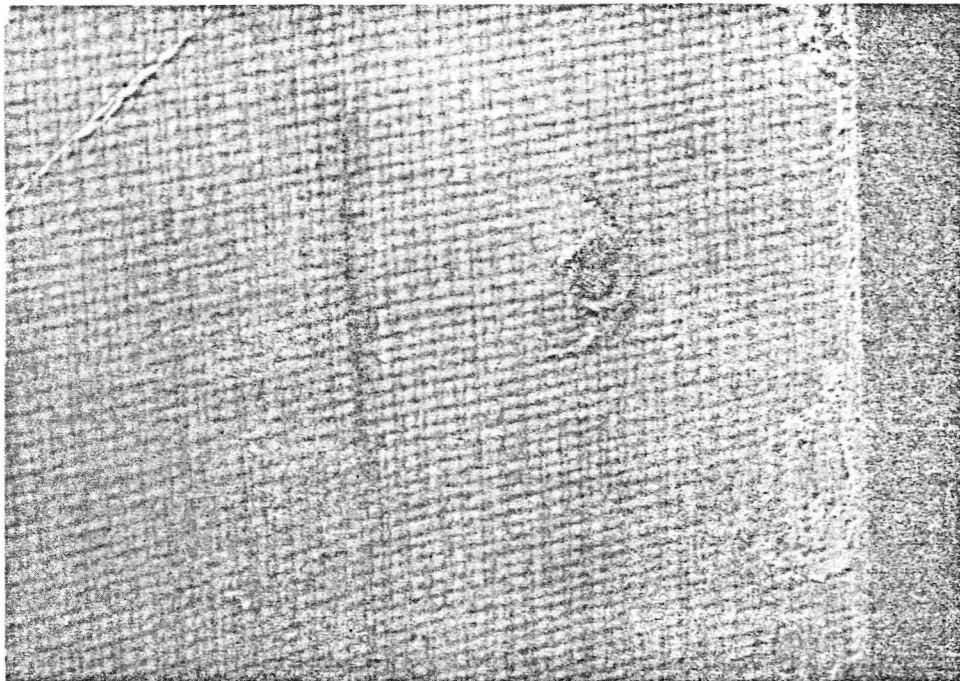


Figure 15. Air Canada LH Wing-Body Fairing - Frayed Hole With Associated Laminate Deformation

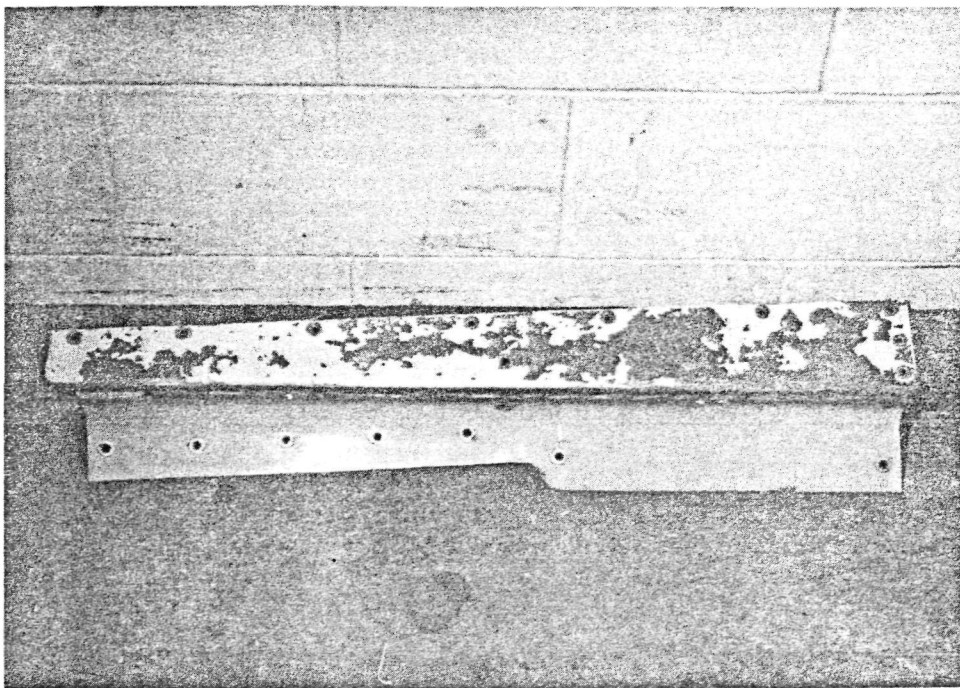


Figure 16. Air Canada LH Wing-Body Fillet - Exterior Surface

paint loss, with exposed Kevlar-49 in the upper portion since this area is not flame sprayed.

- 3) Some fraying of fastener holes was observed, to a greater degree than on the wing-body fairing. One hole had a small associated delamination, and another had a slight convex laminate deformation around the hole. Hole deformation was observed on six holes, including the two mentioned above (Figure 17). These were located mostly in the upper portion of the part. The worst deformation gave the holes (nominally 0.5 cm (3/16 inch) in diameter) a maximum dimension of 0.63 cm (1/4 inch).

RIGHT-HAND AFT ENGINE FAIRING - P/N 1544685-117

- 1) The panel weight was 2.3 kg (5.0 lb). Original weight was also 2.3 kg (5.0 lb).
- 2) The exterior surface was satisfactory with no cracks, debonds, or delaminations (Figure 18). This part had been noted in earlier inspections to have extensive paint blistering which is still occurring despite repainting.
- 3) The interior surface (Figure 19) was free of any defects or damage.
- 4) Fraying was noted on most fastener holes to a slight degree (Figure 20). This fraying was significantly less severe than on the other aft engine fairings observed on the Eastern and TWA aircraft. A few holes (about 21 out of 100) had slight deformations which were more noticeable viewed from the exterior. Four of these were along the intercostals (Figure 21) which unlike any other holes in the three parts are through potted honeycomb core.
- 5) Repair patches observed in the 1974 inspections were unchanged in appearance. These are on the extreme forward wedge end and the extreme aft corner. Air Canada has no record of this repair, and materials and procedures are unknown. The patch color is black (Figure 19) and has a fibrous appearance. This suggests some type of electrical tape overcoated with resin.

RIGHT-HAND WING-BODY FAIRING - P/N 1515599-110

- 1) The exterior surface was satisfactory in appearance with no delaminations or de-bond but with two minor cracks due to impact damage. A crack 0.6 cm (1/4 inch) long in the center, forward area was observed in 1975, and had not grown or propagated. A new crack was observed near the panel center. This was 0.3 cm (1/8 inch) long and rather deep (Figure 22). The panel was very clean, with much less paint loss than the left-hand panel.

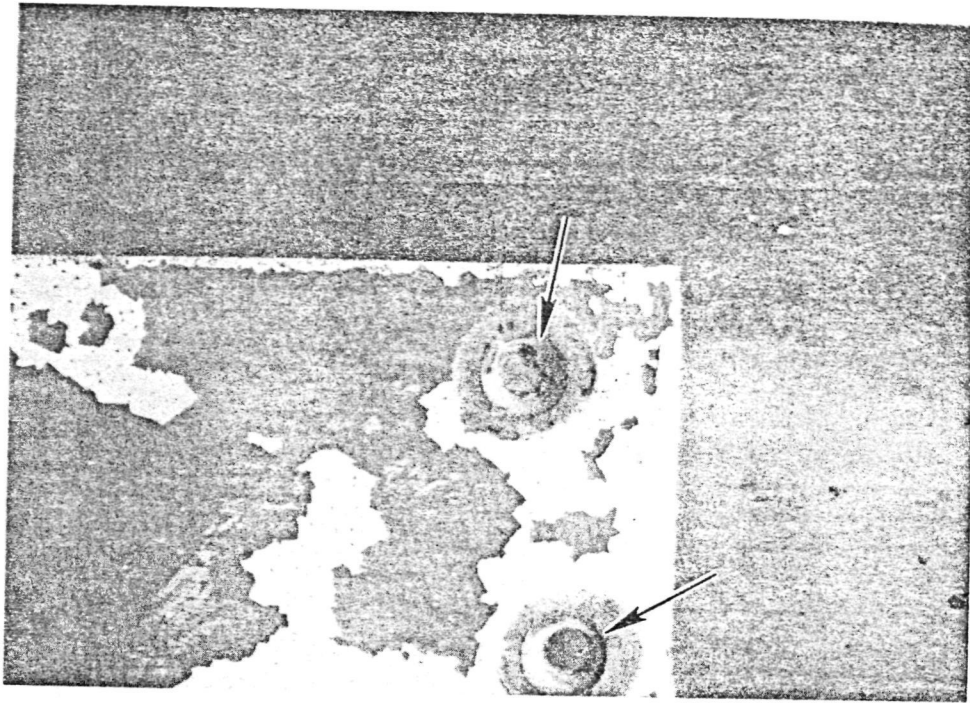


Figure 17. Air Canada LH Wing-Body Fillet - Frayed and Elongated Fastener Holes

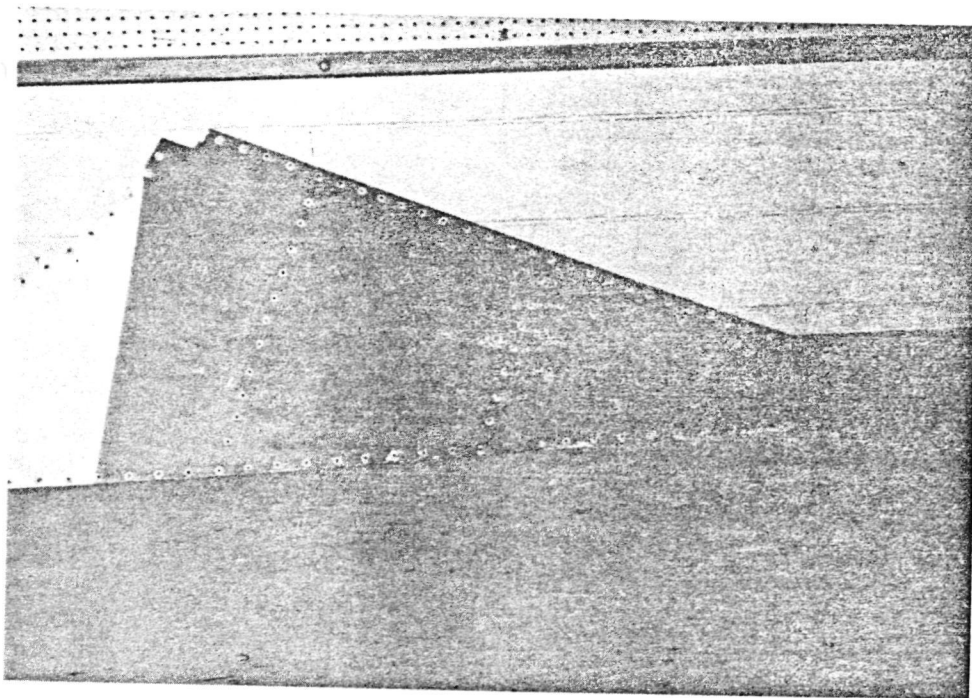


Figure 18. Air Canada RH Aft Engine Fairing - Exterior Surface

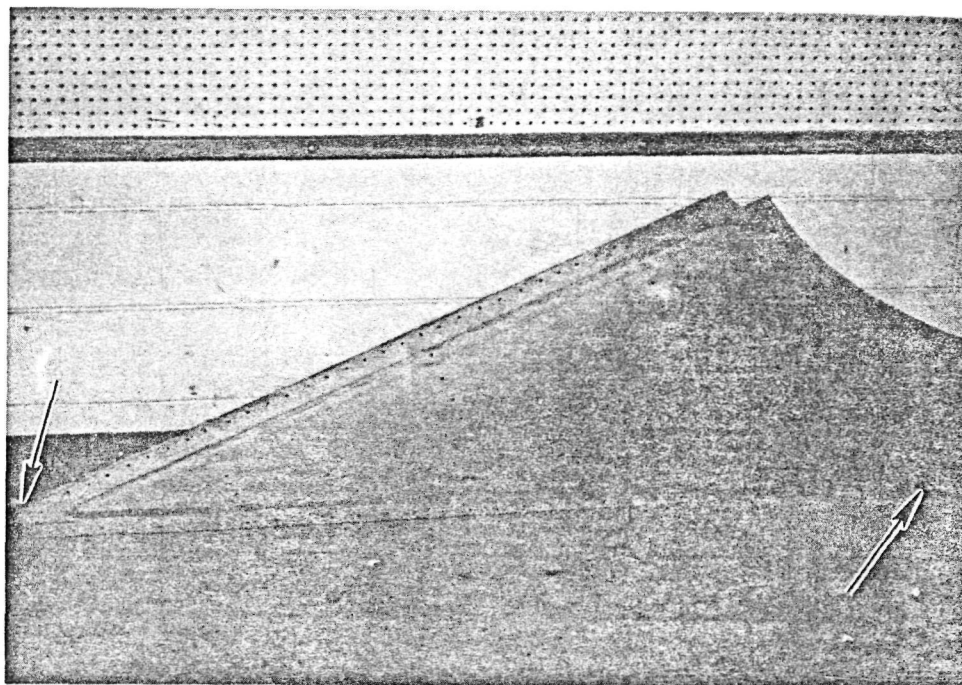


Figure 19. Air Canada RH Aft Engine Fairing - Inner Surface With Repair Patch

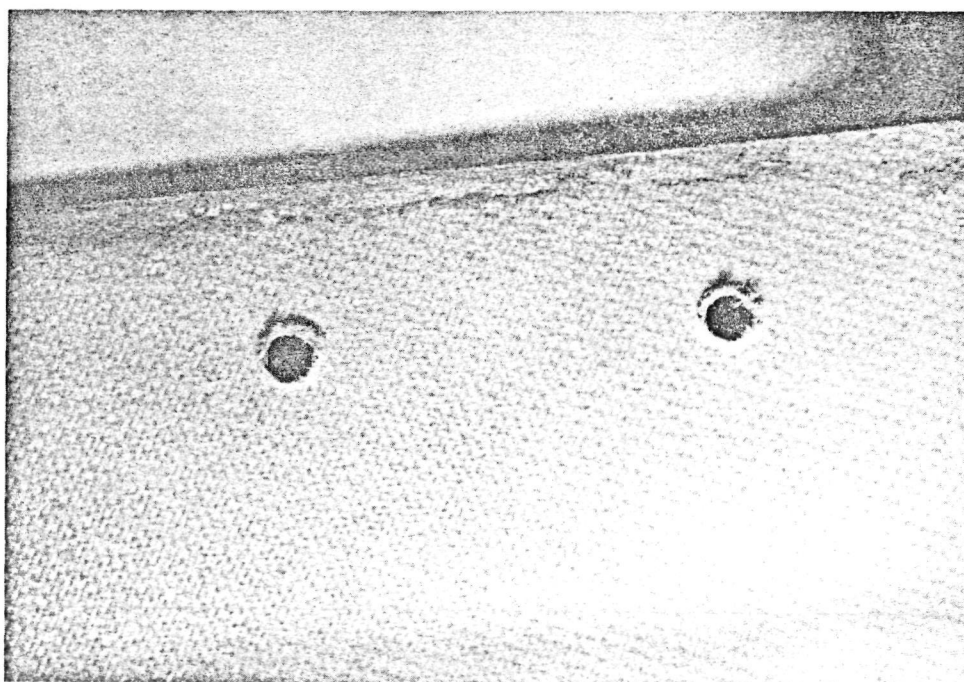


Figure 20. Air Canada RH Aft Engine Fairing - Frayed Fastener Holes

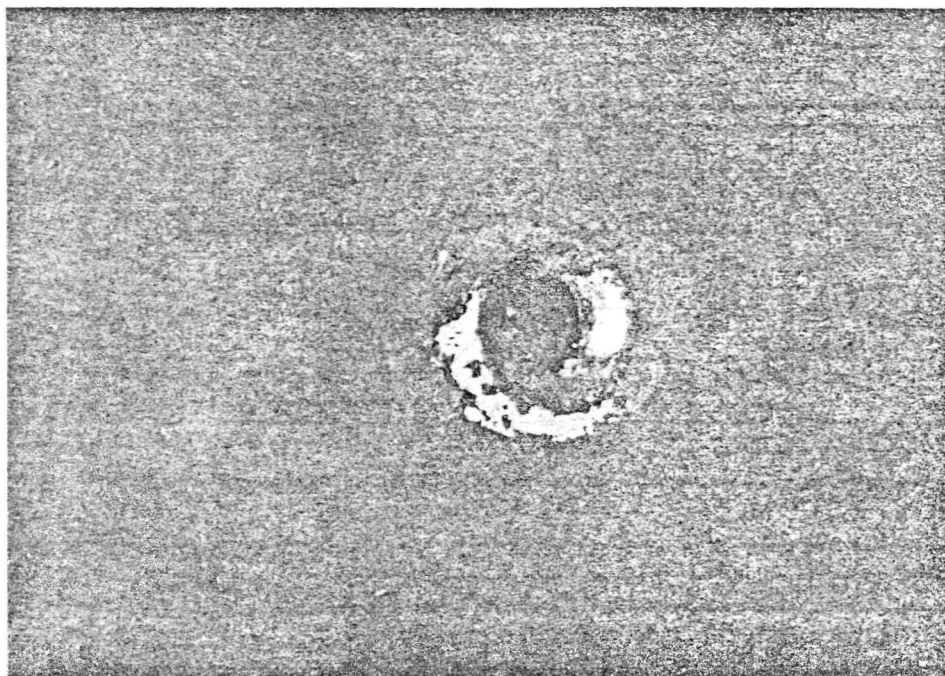


Figure 21. Air Canada RH Aft Engine Fairing - Elongated Intercostal Fastener Hole

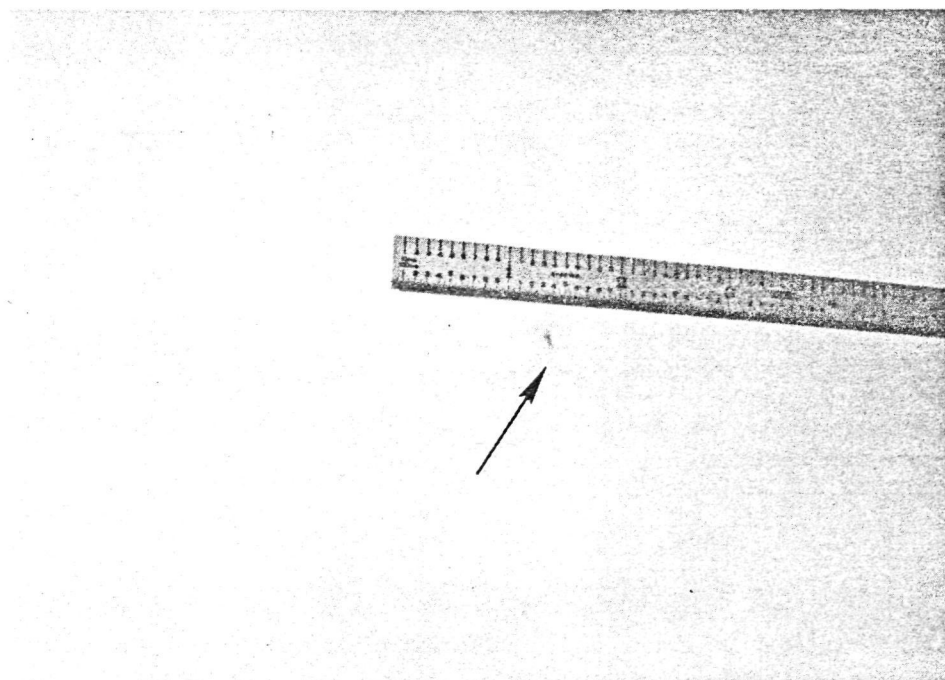


Figure 22. Air Canada RH Wing-Body Fairing - 0.3 cm (1/8 inch) Crack, Exterior Surface

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- 2) Slight gaps were noted between several fastener heads and the panel surface, but not to an extent indicating any serious fastener misalignment.

RIGHT-HAND WING-BODY FILLET - P/N 1544328-110

- 1) The exterior surface had no cracks or other observable damage (Figure 23). There was some paint loss and exposed Kevlar-49.
- 2) This part was observed in the 1975 inspection to have badly out-of-line fasteners with the lower panel bulged outwards as if the part had been forced to fit. Air Canada subsequently removed and reinstalled the part, and the condition was greatly improved with only slight fastener gaps and misalignment, and no panel bulges.

LEFT-HAND AFT ENGINE FAIRING - P/N 1538592-129

- 1) The exterior surface showed no defects or damage, and no paint blistering as on the right-hand part.
- 2) Several fasteners had a slight gap between the fastener head and panel surface, but not to a sufficient degree to indicate any installation problems.

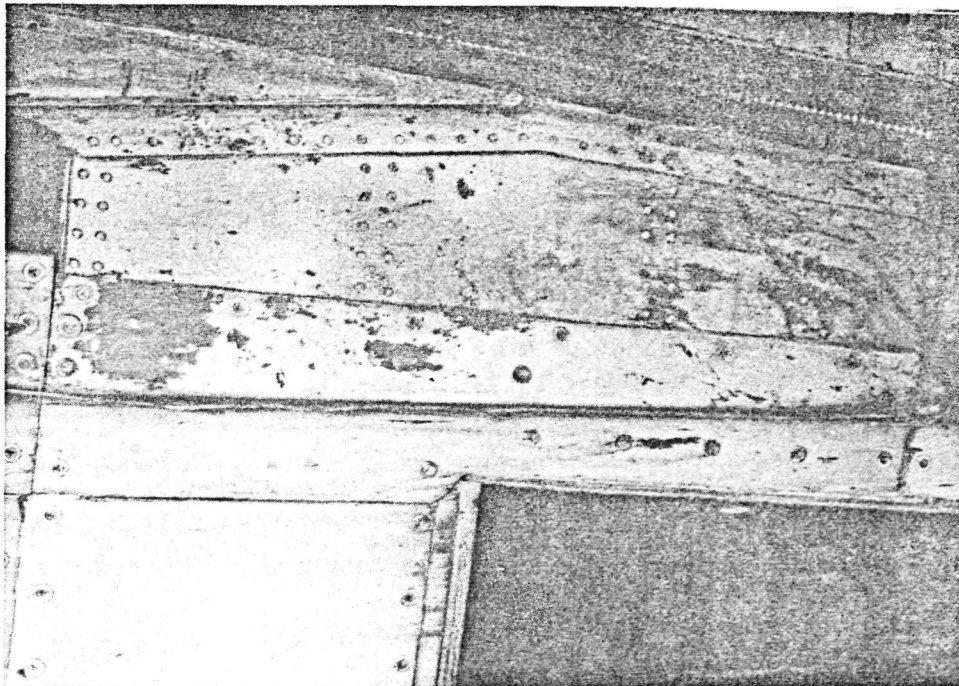


Figure 23. Air Canada RH Wing-Body Fillet - Exterior Surface Showing Bare Kevlar-49 Area

APPENDIX III

DETAIL OBSERVATIONS OF KEVLAR-49 FAIRING PANELS - TWA AIRCRAFT N31030 (SERIAL NO. 1111), OCTOBER 1976

Three of the six Kevlar-49 fairings were removed for detailed inspection, weighing, and inspection of fastener holes and the inner surface. These were the right-hand wing-body fairing sandwich panel, the right-hand solid laminate wing-body fillet, and the left-hand aft engine fairing. The other three parts were inspected in-place on the aircraft. Detail observations on the six parts are outlined below.

RIGHT-HAND WING-BODY FAIRING - P/N 1515599-110

- 1) The panel weight was 7.3 kg (16.1 lb). Original weight was 7.0 kg (15.5 lb).
- 2) The exterior surface was satisfactory in appearance with no delaminations or de-bonds (Figure 24). A slight loss of paint was noted along the forward edge, but flame spray was intact in all areas. A small crack 0.3 cm (1/8 inch) long, was noted in the lower aft area, which may have only been through the paint. A slight depressed area, 2.5 cm x 0.6 cm (1 inch by 1/4 inch), was observed near the aft edge which is the probable location of a repair made after the 1974 inspection prior to reinstallation of the panel on Ship 1111.
- 3) The interior surface was free of defects or damage with the Tedlar film intact.
- 4) No fraying of fastener holes was visible from the exterior surface, but slight fraying was visible from the inner surface (Figure 25). A convex deformation of the laminate was visible around the fastener holes on the inner surface. This deformation was only in the immediate area around the holes, and occurred on all holes on the top, forward, and aft edges. There was some hole deformation along the bottom edge where five holes were deformed to a maximum of 0.3 cm (1/4 inch) diameter from the nominal 0.5 cm (3/16 inch) diameter (Figure 26). A lesser degree of deformation was observed on two holes each of the upper and forward edges.

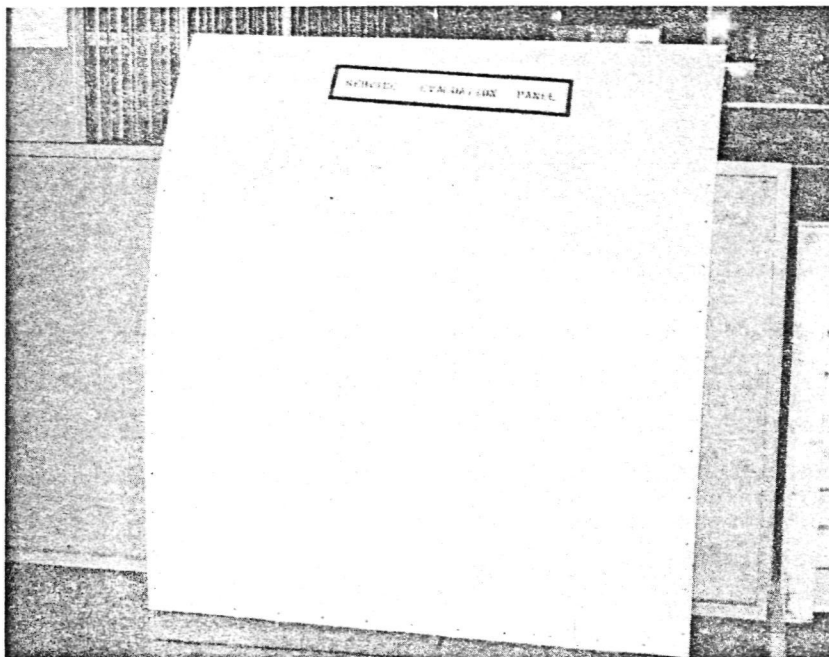


Figure 24. TWA RH Wing-Body Fairing - Exterior Surface

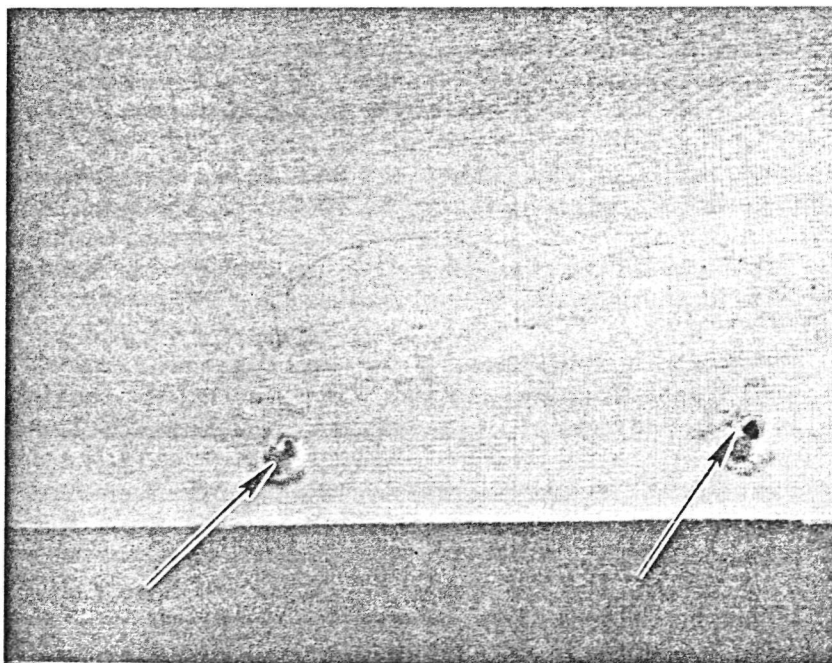


Figure 25. TWA RH Wing-Body Fairing - Frayed Fastener Holes Adjacent to Filled Fastener Holes

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- 5) The two aft holes on the bottom edge had been re-located when the panel was reinstalled on Ship 1111. These holes were not the ones showing deformation and were frayed to about the same degree as the other holes. One hole had been drilled partly through the filled area where the holes had been previously located, but there was no deformation in this area. The filled areas (which contained a chopped fiberglass filled epoxy resin) showed no visible defects or damage (Figure 25).

RIGHT-HAND WING-BODY FILLET - P/N 1545328-110

- 1) Panel weight was 0.64 kg (1.4 lb).
- 2) No cracks, delamination, loss of paint, or other defects or damage was noted on exterior or inner surfaces (Figure 27).
- 3) Fraying of holes was not visible from the exterior, but from the inner surfaces slight fraying was visible around most fastener holes. Two holes on the lower aft edge were heavily frayed and showed hole deformation and elongation (Figure 28). Six holes on the upper edge were deformed, with three on the aft end slightly elongated and three in the forward end more severely elongated. Maximum elongation was to a dimension of 0.3 cm (1/4 inch) from the nominal 0.5 cm (3/16 inch) diameter.
- 4) One hole in the lower aft corner had been relocated. The relocated hole was not drilled through the filled area. The filled area showed no visible defects or damage.

LEFT-HAND AFT ENGINE FAIRING - P/N 1538592-129

- 1) Panel weight was 2.40 kg (5.3 lb).
- 2) The exterior surface was free of cracks, delaminations, skin-core debonds, or other defects or damage (Figure 29), but there was some paint loss. In about half of this area, the flame spray had also been lost (Figure 30). The flame spray on this part was re-applied during the reinstallation on Ship 1111.
- 3) The inner surface was also free of defects or damage (Figure 31). The repair on the inner surface, where a skin-core delamination had occurred during panel rework, showed no visible delamination or other defects or damage. The vapor barrier coating, applied to the inner surface during rework, was adhering satisfactorily and had no signs of damage. Some porosity was noted, however.
- 4) No fraying of fastener holes was visible from the exterior surface. From the inner surface much less fraying was visible than on the other panels (Figure 32). All the fastener holes were relocated

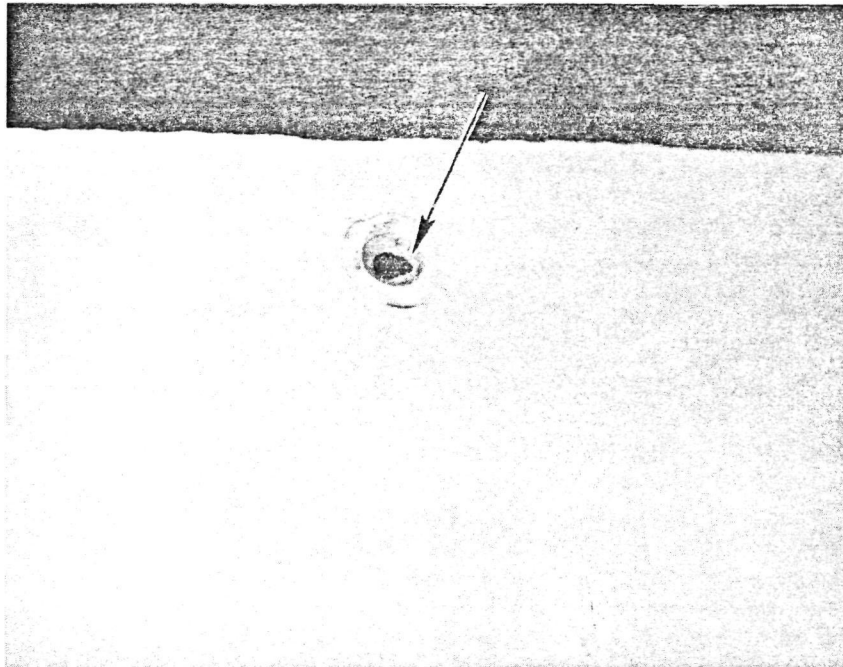


Figure 26. TWA RH Wing-Body Fairing - Elongated Fastener Hole

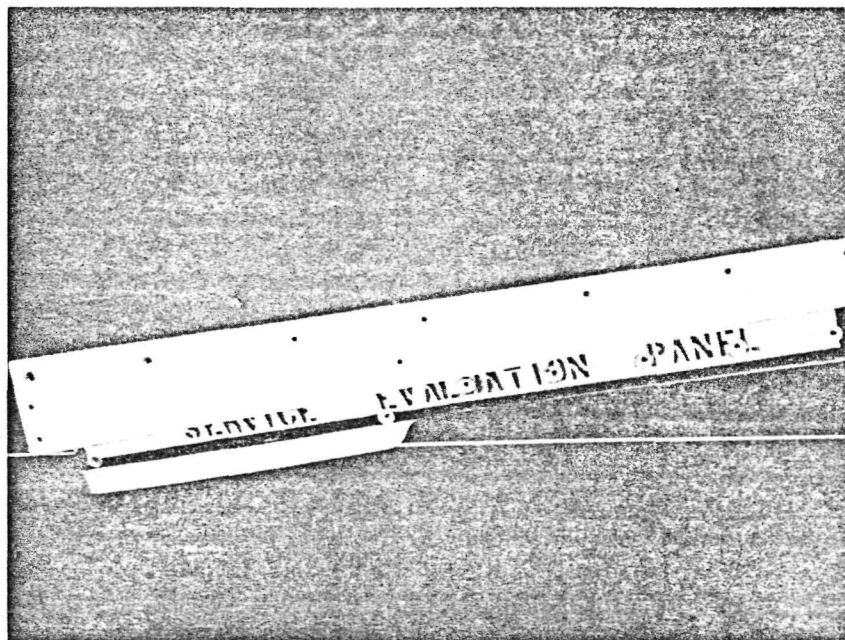


Figure 27. TWA RH Wing-Body Fillet - Exterior Surface

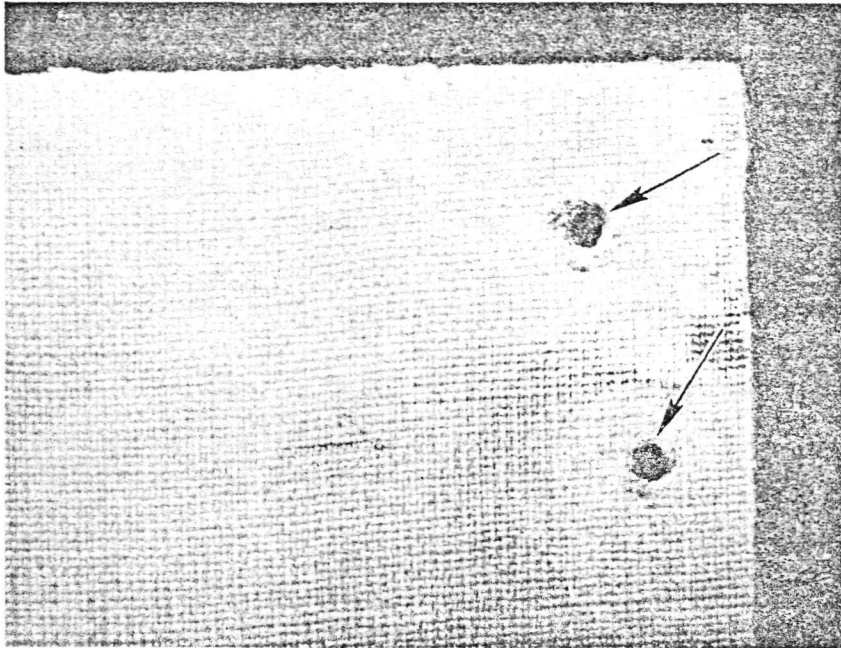


Figure 28. TWA RH Wing-Body Fillet - Frayed and Elongated Holes

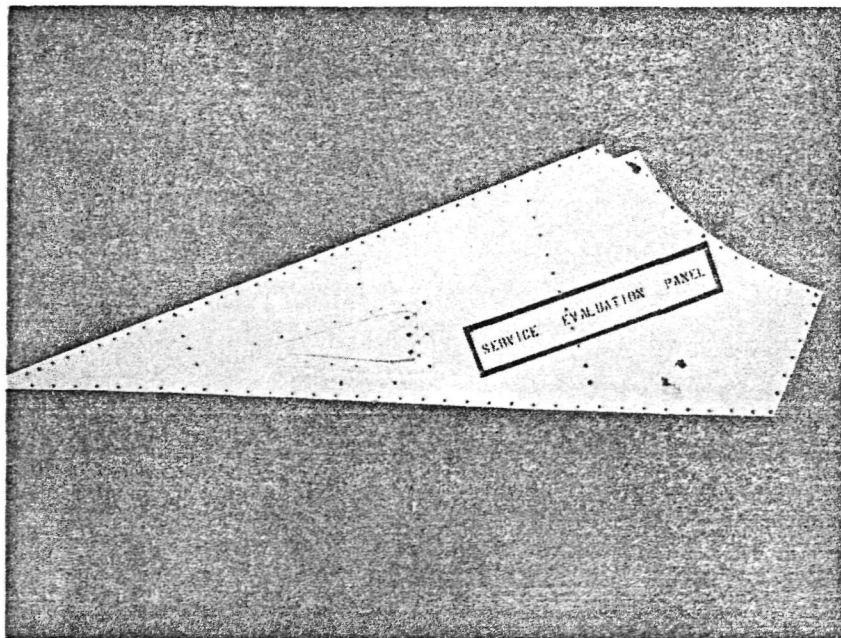


Figure 29. TWA LH Aft Engine Fairing - Exterior Surface

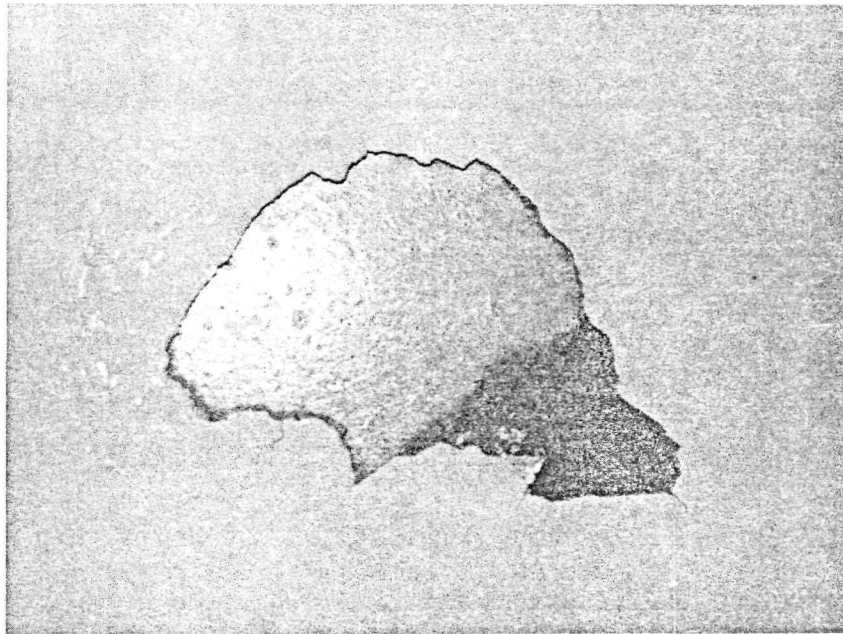


Figure 30. TWA LH Aft Engine Fairing - Showing Loss of Paint and Flame Spray

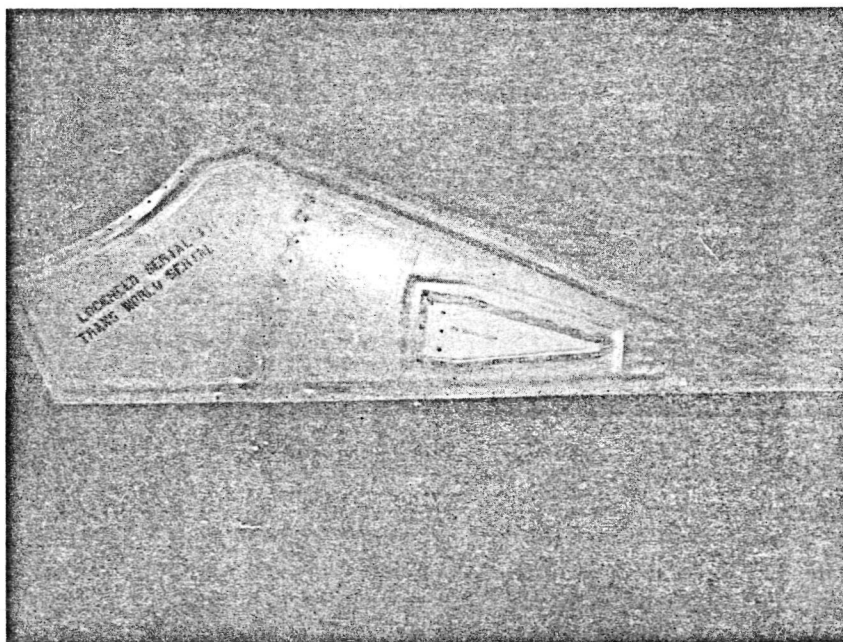


Figure 31. TWA LH Aft Engine Fairing - Inner Surface Showing Vapor Barrier Coating

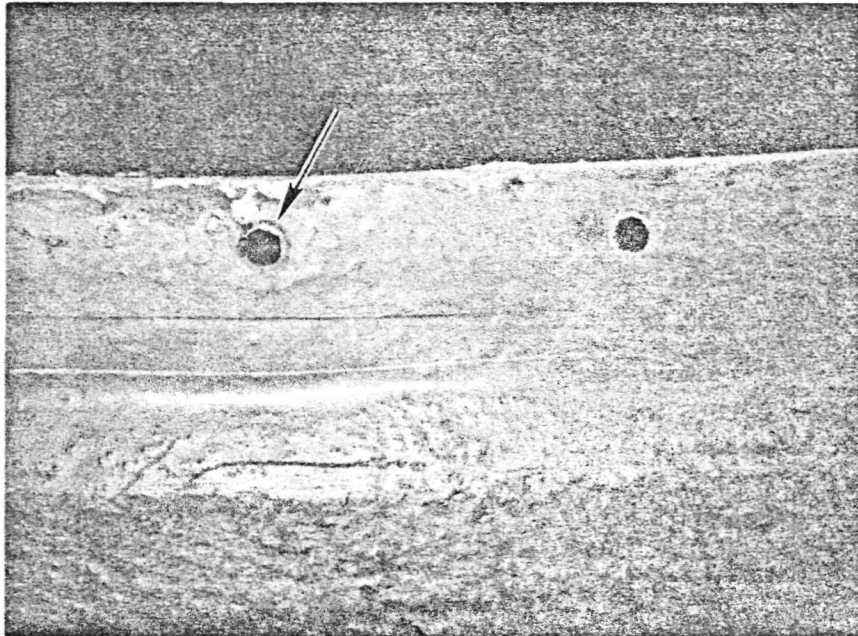


Figure 32. TWA LH Aft Engine Fairing - Fastener Holes

on this panel prior to reinstallation, and a single strip of resin impregnated 120 glass cloth had been applied over the filled holes on both surfaces. This accounted for the lack of Kevlar-49 fiber fraying.

- 5) The majority of holes were not significantly deformed, but several holes showed more severe elongation than noted in any of the other panels on the three ship sets. Six holes were elongated to a maximum dimension of 1.6 cm (5/8 inch), and seven holes were elongated to 0.6 cm (1/4 inch) dimension (Figure 33). These holes were mostly on the lower edge with the rest along the aft edges. Two holes in the aft intercostal, which are drilled through filled honeycomb and which were also relocated, showed some elongation; but the other intercostal holes had no deformation.

LEFT-HAND WING-BODY FAIRING - P/N 1515599-109

- 1) The exterior surface showed no cracks, delaminations, debonds or other defects or damage.
- 2) No out-of-line fasteners were noted, and no fasteners had a significant gap between the fastener head and the panel.

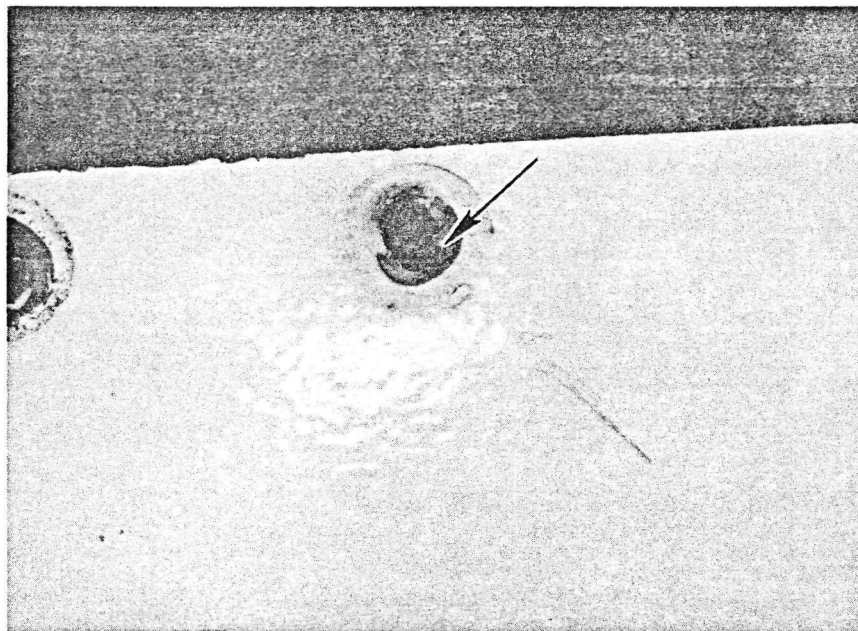


Figure 33. TWA LH Aft Engine Fairing - Elongated Fastener Hole

LEFT-HAND WING-BODY FILLET - P/N 1545328-109

- 1) No cracks, delamination, loss of paint, or other defects or damage noted. No misalignment of fasteners noted (Figure 34).
- 2) The upper portion of the panel was extremely dirty, but there was no evidence of Skydrol contamination.

RIGHT-HAND AFT ENGINE FAIRING - P/N 1544685-117

- 1) The exterior surface showed no cracks, delaminations, debonds or other visible defects or damage (Figure 35). Some loss of paint was noted, but flame spray was intact.
- 2) There was no significant fastener misalignment or excessive gaps between the fastener heads and the panel. A slight bulge was noted in the panel along the lower aft edge, however, indicating the panel may have been forced to fit in that area.

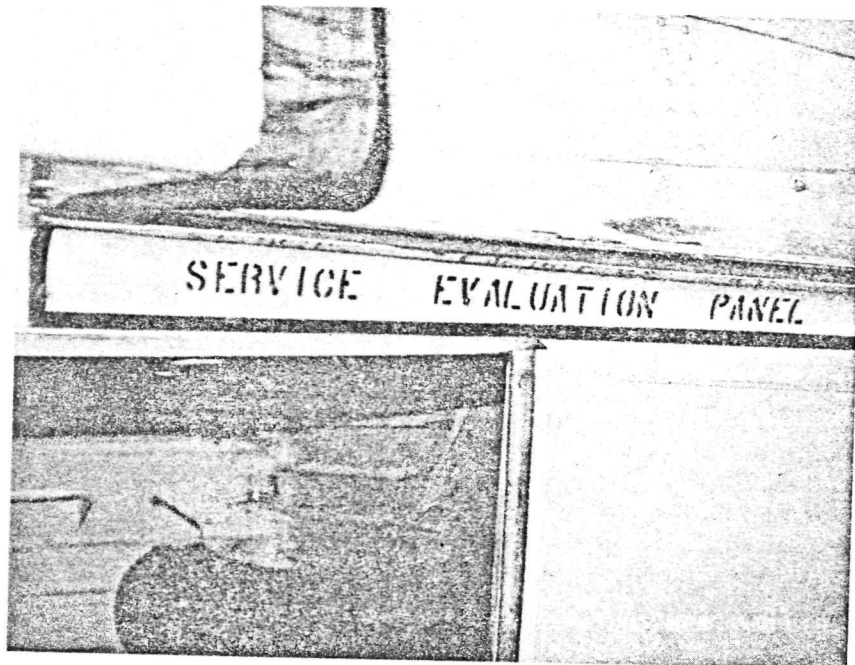


Figure 34. TWA LH Wing-Body Fillet - Exterior Surface

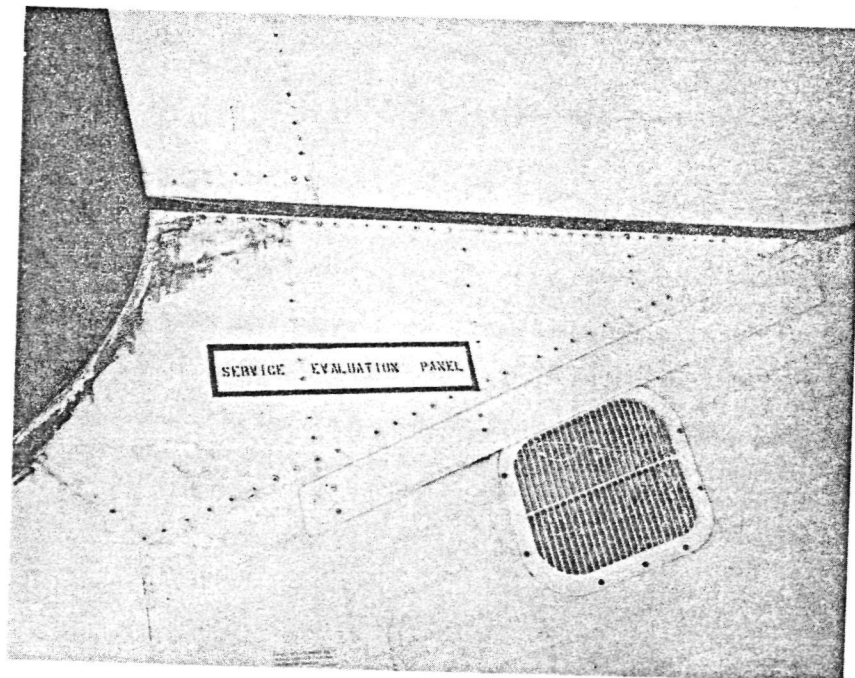


Figure 35. TWA RH Aft Engine Fairing - Exterior Surface